LOAN DOCUMENT

PHOTOGRAPH THIS SHEET

DTIC ACCESSION NUMBER

LEVEL

INVENTORY D

RIA-78-U165

DOCUMENT IDENTIFICATION

MAR 1978

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

~~"DTIC USERS ONLY"~~

DISTRIBUTION STATEMENT

ACCESSION FOR
NTIS GRA&I
DTIC TRAC
UNANNOUNCED
JUSTIFICATION

BY

DISTRIBUTION/

AVAILABILITY CODES

DISTRIBUTION	AVAILABILITY AND/OR SPECIAL	
A-1		

DISTRIBUTION STAMP

DATE ACCESSIONED

DATE RETURNED

19960904 104

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NUMBER

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC

HANDLE WITH CARE

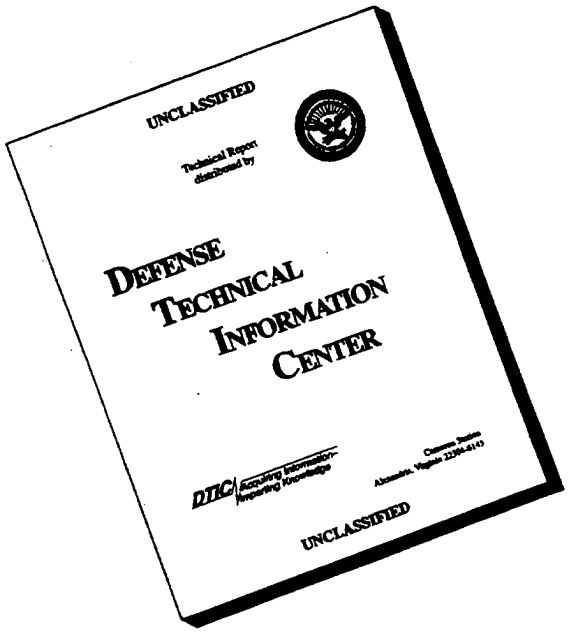
DTIC FORM 70A JUN 90

DOCUMENT PROCESSING SHEET

PREVIOUS EDITIONS MAY BE USED UNTIL STOCK IS EXHAUSTED.

LOAN DOCUMENT

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

RIA-78-U165

NUREG-0419

OCCUPATIONAL RADIATION EXPOSURE AT NRC-LICENSED FACILITIES 1975

Walter S. Cool

Office of Standards Development
U. S. Nuclear Regulatory Commission

Available from
National Technical Information Service
Springfield, Virginia 22161
Price: Printed Copy$4.50 ; Microfiche $3.00

The price of this document for requesters outside of the North American Continent can be obtained from the National Technical Information Service.

NUREG-0419

OCCUPATIONAL RADIATION EXPOSURE AT NRC-LICENSED FACILITIES 1975

Walter S. Cool

Manuscript Completed: January 1978
Date Published: March 1978

Occupational Health Standards Branch
Office of Standards Development
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

ABSTRACT

By letter dated August 25, 1976, licensees of the Nuclear Regulatory Commission were requested to submit, as a voluntary one-time action, a statistical summary report of whole-body personnel monitoring results for their activities during 1975. This report presents these personnel monitoring data in the form of tables and log-probability plots that facilitate evaluation and comparison of the data. Licensee estimates of the effort (man-hours and total cost) expended in preparing the statistical summary report are also presented.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
USE OF DATA	2
ANALYSIS OF DATA	3
RESERVATIONS REGARDING THE DATA	8
COST OF REPORTING	9
REFERENCES	10

LIST OF TABLES

		Page
Table 1	Summary of 1975 Voluntary Monitoring Data	11
Table 2	1975 Monitoring Data by Licensee Functional Group	13
Table 3	Distribution of Estimated Doses - 1975 Voluntary Data	14
Table 4	Extrapolated Total Collective Dose by Category of Licensee (man-rems)	16
Table 5	Average Collective Dose Per Licensee in a Given Category (man-rems)	17
Table 6	Average Individual Dose by Category	18
Table 7	Average Individual Dose, Extrapolated Collective Dose, and Ω 1975 Voluntary Data	19
Table 8	Average Individual Dose, Extrapolated Collective Dose, and Ω 1973-1975 10 CFR §20.407 Data	21

LIST OF FIGURES

Figure 1	1975 Voluntary Data - Academic Licensees	22
Figure 2	1975 Voluntary Data - Medical Licensees	23
Figure 3	1975 Voluntary Data - R&D and Marketing Licensees	24
Figure 4	1975 Voluntary Data - Well Logging, Other Measurement Systems, and Waste Disposal - Burial Licensees	25
Figure 5	1975 Voluntary Data - Byproduct, Source, and Special Nuclear Material Licensees	26
Figure 6	Composite 1975 Voluntary Data and §20.407 Data	27
Figure 7	§20.407 Power Reactor Data - 1973-1975	28
Figure 8	§20.407 Radiographer Data - 1973-1975	29
Figure 9	§20.407 Fuel Processing and reprocessing Data - 1973-1975	30
Figure 10	§20.407 Byproduct Manufacture and Distribution Data - 1973-1975	31
Figure 11	Composite Annual Salaries - 1973-1975 and §20.407 Data	32
Figure 12	Effort Needed to Prepare Statistical Summary Report	33
Figure 13	Cost of Preparing Annual Statistical Summary Report	34

OCCUPATIONAL RADIATION EXPOSURE
AT
NRC-LICENSED FACILITIES
1975

INTRODUCTION

The Nuclear Regulatory Commission and its predecessor, the Atomic Energy Commission, have required the submission of annual reports on personnel monitoring from four categories of licensees since December 1968. These four categories (specified in §20.407 of 10 CFR Part 20 as power reactor licensees, industrial radiographers, fuel processors and reprocessors, and certain large commercial suppliers of byproduct materials) were considered to involve the greatest potential for significant occupational radiation doses.

The original rule required reporting of the actual estimated exposures to any body part of a named individual that exceeded in a year the applicable quarterly limit. In January 1974 the regulation was changed to require the annual reporting of only a statistical summary of the estimated whole-body exposures. This amendment provided additional data by requiring the submission of a statistical summary of the whole-body exposures estimated to have been received by all individuals who are required to be monitored pursuant to other portions of the NRC regulations. Further, some licensees choose to include data on individuals who are provided with personnel monitoring service as part of good health physics practice even though such monitoring is not required. The data submitted by licensees pursuant to §20.407 of 10 CFR Part 20 are summarized in annual reports (Refs. 1,2) and have been discussed in other reports (Refs. 3,4). Some of these data are included in this report for purposes of comparison.

In May 1975, NRC published a notice of proposed amendment to its regulations that would, if adopted, extend to all licensees the requirement for the submission of an annual statistical summary report of personnel monitoring data. Comments on the proposed amendment raised questions regarding the value of the data to be obtained and the reporting burden imposed on licensees. The NRC recognized the need for additional information to evaluate the benefit to be obtained from extending the reporting requirement to all licensees and the burden that the proposed extension of the reporting requirement would impose on licensees and also to test the assumption that the four categories of licensees currently required to report involve the greatest potential for significant doses. Accordingly, in a letter dated August 25, 1976, the NRC requested all licensees to submit, as a voluntary one-time action, a statistical summary report of the whole-body personnel monitoring results for their activities during 1975.

There were 1,179 responses to the request. Reports were received from 1,175 out of 8,221 (14%) materials licensees in 40 out of 53 categories. There were responses from three research reactor licensees and one test reactor licensee. Data are presented in this report for 50,112

monitored individuals; 20,992 (41.9%) of those individuals were reported to have received measurable doses. A total of 253 respondents (21%) indicated that they had not monitored any individuals during 1975. A total estimated dose of 4,925 man-rems was reported. That is an average of 0.1 rem per monitored individual and an average of 0.23 rem per individual with measurable exposure. If the data are extrapolated for the categories represented with the assumption that the fraction of licensees not reporting is comparable in number of workers and exposure experience, a total of 245,400 individuals would have been monitored and a total estimated dose of 22,900 man-rems would have been received. The categories of licensees not represented by any respondents are not considered to comprise either a significant number of individuals or potential for radiation exposure.

USE OF DATA

The NRC staff considers the information obtained from the required annual reports to be essential to the evaluation of the risk of radiation exposure associated with the related activities.

Following the trends in occupational radiation exposures permits the NRC staff to maintain awareness of changes in the total radiation burden from a given type of licensed activity and to be able to estimate the total occupational radiation dose resulting from all NRC licensed activities. It also permits some assessment of the degree of radiation protection efficiency that is being maintained. The NRC staff also believes that licensees need to develop this information for their own evaluation and action in control and direction of their radiation safety programs.

The personnel monitoring data already received provide a base that may be used to develop a variety of value/impact analyses. They may be used as one indicator in the assignment of priorities for inspection and enforcement actions. The data are being used by the staff to identify situations needing further study in order that regulations and regulatory guides can be developed requiring or recommending action to be taken in the design and operation of licensed facilities to keep occupational radiation exposures "as low as is reasonably achievable." For example, it is relevant to compare the potential increase in collective radiation dose, that is, occupational dose plus dose to the general population, when considering the controls to be imposed on the release of radioactive material in effluents to unrestricted areas. As another example, the personnel monitoring data are used to establish priorities with respect to the need for regulatory attention by permitting a perspective to be drawn through consideration of the collective dose in addition to individual and average doses. In some cases, more regulatory attention may be required for licensees with larger collective doses than for licensees with larger individual doses.

It should be noted, however, that the personnel monitoring data do not permit evaluation of what occupational exposures are "as low as is reasonably achievable." Such evaluation requires study of the specific factors associated with a specific facility and activity.

ANALYSIS OF THE DATA

The voluntary one-time personnel monitoring data for 1975 are found to have log-normal distributions,* as has been reported for other distributions of personnel monitoring data (Refs. 3,4). The departure from the straight-line log-probability plot, particularly above annual doses of 2 or 3 rems, is interpreted to reflect pressure to meet the recommendations of the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) and the regulatory limits of the Nuclear Regulatory Commission.

A reference distribution has been developed by the United Nations Scientific Committee on the Effects of Atomic Radiation (Ref. 4) such that the distribution of annual doses is log normal, the mean or arithmetic average of the annual dose distribution is 0.5 rem (one-tenth of the ICRP maximum permissible average annual whole body dose), and the percentage of individuals exceeding the annual dose of 5 rems is 0.1 percent. (Note that the median or 50% value is about 0.34 rem.) These properties were selected arbitrarily to define the distribution as one complying with the intent of the ICRP. Further, to aid in the evaluation and comparison of distributions of monitoring data, a factor Ω has been described (Ref. 4). It is defined as a dimensionless quantity that is the ratio of the fraction of the collective dose (S) due to annual doses above 1.5 rems ($S_{1.5}$) for the observed distribution to the fraction for the reference distribution.** For any observed distribution $\Omega = 3.23S_{1.5}/S$. The "reference distribution" line has been imposed on each of the log-probability plots in this report, and tables showing the average dose, collective dose, and Ω are presented for the voluntary one-time data and for the data reported pursuant to §20.407 of 10 CFR Part 20 for the period 1973 - 1975.

Table 1 presents a summary of the data including the fraction of licensees in each category who reported and the number of those licensees who monitored any individuals during 1975. The total number of individuals who were monitored by those licensees and the total collective dose they were estimated to have received have been extrapolated to correct for the fraction of licensees not reporting. The reported collective dose has been averaged over the total number of individuals monitored and also averaged over the number of individuals who received measurable

---

* A variable such as the annual occupational radiation exposure of individual workers is said to be "log-normal" when the frequency distribution of the logarithm of the exposure can be reasonably approximated by the normal (Gaussian) curve, with appropriate mean and standard deviation. Plotted on log-probability paper, on which cumulative probabilities are laid off on the vertical axis at distances proportional to the corresponding number of standard deviations above or below the median with dose plotted on the horizontal axis on a logarithmic scale, the function becomes a straight line. Any given set of data from a finite-size sample can, of course, only give an approximate representation of a presumed smooth underlying function. The log-probability plot is simple to use and facilitates intercomparisons between types of activities, between individual facilities conducting similar activities, and between years of experience.

** Thus, Ω is a quantity by which the fraction of the collective dose from entries greater than 1.5 rems for a given licensee category can be compared with that same fraction taken from the "reference distribution" in Reference 4. To obtain Ω, the fraction taken from the licensee data is divided by the fraction from the reference distribution. Values of Ω greater than unity indicate that the licensee category is experiencing doses greater than 1.5 rems to a greater extent than would occur in the reference distribution.

doses. The (large) number of individuals who did not receive measurable doses includes visitors and other individuals who would not have been required to be monitored and will vary with the administrative policy of the licensees involved. However, average dose to all individuals who were monitored is important not only because it represents the risk of radiation exposure to the workers in each category, but also because the licensees' efforts to maintain radiation doses low will be reflected by shifts in the average dose. Consideration of the average individual doses and the collective dose (extrapolated) provides an estimate of the risk of radiation exposure associated with each of the activities and, by summation, of the total NRC-licensed industry.

Table 2 combines several elements of the monitoring data for certain categories of licensees in functional groupings. It indicates that the 13,500 man-rems of occupational dose associated with medical programs exceeds the dose associated with any other grouping except power reactors. This number should be doubled to estimate the total U.S. occupational collective dose, including Agreement State licensees. The resulting dose is considerably larger than that for power reactors. The dose estimated for medical programs is of particular interest because the population of workers involved is assumed to include a high percentage of young women. Dose to pregnant women involves somatic risks to the embryos and fetuses in addition to the somatic risks to the adult workers and the genetic risk of the doses. The extrapolated collective doses estimated for research and development, well logging, and other measurement systems also approach or exceed 1,000 man-rems.

Table 3 provides the distributions of estimated doses reported for each of the categories of licensees. It has been assumed that the distributions submitted by the fraction of licensees reporting are representative of the total. The relationship and significance of the data are more easily recognized by consideration of the log-probability plots and comparisons in Figures 1 through 11.

Table 4 presents the data on extrapolated collective dose by category of licensee. Six categories of licensees (Institutional Broad Medical, Institutional Other Medical, Private Practice, Teletherapy, Well Logging, and Other Measurement Systems) in addition to the four categories reporting pursuant to §20.407 of 10 CFR Part 20 probably exceeded 1,000 man-rems in 1975. Twelve categories of licensees (Academic Other, Other Medical, Marketing Broad, Marketing Other, R & D Broad, R & D Other, Civil Defense, Uranium Mills, Other Uranium Uses >150 kg, Unencapsulated SNM, Other SNM Sources, and Research Reactors) experienced collective doses between 100 and 1,000 man-rems.

Table 5 presents the data on average collective dose per licensee in a given category. Seven categories of licensees (Institutional Broad Medical, Well Logging, Waste Disposal - Burial, Transportation Type B, Uranium Mills, UF_6 Production, and Unencapsulated SNM) experienced average doses in excess of 10 man-rems per licensee. These data permit comparison of licensees within each category. Licensees who experience doses above the average for their category are more likely to benefit from (increased) effort to reduce occupational doses. Consideration of the facilities, equipment, and practices of licensees experiencing doses below the average for their category should be helpful in this regard.

Table 6 presents the data on averaged individual doses. Individuals working for licensees in categories that show values of "Average Dose" nearly as large as the "Average Measurable Dose" experience relatively uniform external radiation levels in the working areas (Fuel Storage), perform closely related job functions (Medical categories, Well Logging, Waste Disposal - Burial), are subject to administrative controls that distribute the dose across the work force (as by rotation of job assignments) (Uranium Mills), or are monitored and reported only if necessary. Licensees in categories in which the "Average Measurable Dose" is significantly higher than the "Average Dose" involve operations in which a small percentage of the individuals receive most of the dose (Academic, Waste Disposal - Other, Irradiators, Unencapsulated SNM) or monitor many visitors or other individuals who would not have been required to be monitored.

Figures 1 through 11 are log-probability plots of the personnel monitoring data. Note that, on these plots, shifts upward or to the left indicate lower doses. The reference distribution line has been imposed on each of these plots, and a table has been inserted showing the average individual dose, the extrapolated collective dose in man-rems, and Ω for each distribution of data depicted on the graph.

The plots for academic licensees presented in Figure 1 indicate that these activities are experiencing exposures well within the regulatory limits. The plots compare favorably with the reference distribution. They are of interest also because of the difference between the two categories of academic licensees. It may be inferred that the greater potential for exposure associated with the larger, more complex activities of institutions operating under broad licenses is more than compensated by the internal administrative controls, larger and frequently better-equipped health physics staffs, etc., required in support of the broad license.

The log-probability plots and data presented in Figure 2 for five categories of medical licensees show that the activities of those licensees contribute a large collective dose to the population. This contribution involves relatively small doses to a large number of individuals. The plots indicate that a larger number of individuals would be expected to receive doses greater than 5 rems if it were not for pressure to meet regulatory limits (5 rems per year). Individuals involved in teletherapy and private practice experience doses above 1.5 rems more frequently than would be consistent with the reference distribution. Individuals in private practice experience higher exposures than individuals in the institutional programs. Again, it is implied that factors associated with broad licenses result in lower doses in spite of the fact that the programs of broad medical licensees are usually larger and more complex than those of other medical licensees.

Figure 3 portrays the monitoring experience of licensees involved in research and development (R & D) and marketing. The exposures received by the marketing categories are higher than those received by R & D licensees and probably reflect the higher levels of activity being processed and handled under those licenses. However, because of the smaller number of individuals involved (about 10,000 in marketing and about 34,000 in R & D), marketing contributes a smaller collective dose than R & D. The plot of data for the large byproduct manufacturing and distributing licensees currently reporting pursuant to §20.407 of 10 CFR Part 20 has been added for comparison purposes. It is apparent that the activities of the latter licensees involve significantly higher individual doses, including more than twice the contribution to

collective dose by individuals receiving more than 1.5 rems per year, than would be consistent with the reference distribution ($\Omega = 2.08$). Marketing activities under broad license experienced slightly lower doses than "Marketing Other" licensees. However, R & D programs under broad license experienced significantly higher doses than "R & D Other" licensees. This difference is probably due to a marked difference in the quantities of materials being used in the programs of the two categories of licensees. The plots for "R & D Broad" and "Marketing Other" indicate that more individual doses would be expected to exceed 5 rems per year if it were not for pressure to meet the NRC occupational dose limits.

Figure 4 plots the distributions for "Waste Disposal - Burial" and "Well Logging." These two categories have high average individual doses. "Waste Disposal - Burial" also has the highest percentage of the collective dose contributed by individuals receiving more than 1.5 rems per year ($\Omega = 2.48$). The operations of these licensees involve work in close proximity to packaged wastes presenting relatively high external radiation levels for prolonged periods of time. The plot indicates considerable effort has been made to maintain doses below 5 rems per year. Because of the small number of individuals involved (65), the collective dose is not large. The operations of well logging licensees involve the handling of tracer materials and relatively large sealed sources under field conditions. The plot does not reflect great effort to maintain exposures below 5 rems per year. The operations of licensees in both of these categories warrant study by NRC and inspection and positive measures by licensees to ensure that occupational doses are maintained as low as is reasonably achievable (ALARA).

The plot for "Other Measuring Systems" reflects relatively low doses, well within the regulatory limits, and compares favorably with the reference distribution. The plot departs from the log-normal (straight line), perhaps because the types of gauging installations involved constitute more than one type of work. In some cases the devices are fixed and require very little service involving radiation exposure. Other devices are portable or subject to relocation or certain services which do involve relatively low doses.

Figure 5 presents plots of the composite experience of byproduct, source, and special nuclear material (SNM) licensees (other than those reporting pursuant to §20.407 of 10 CFR Part 20). All three distributions are well within regulatory limits and compare favorably with the reference distribution. While the average of individual doses is low (0.04 rem) for SNM licensees, the percentage of the collective dose contributed by individuals receiving more than 1.5 rems per year is higher than would be consistent with the reference distribution ($\Omega = 1.31$). The data indicate that source material licensees experience higher dose distributions than byproduct material or SNM licensees. It is believed that most source material licensees control their operations based on factors associated with the intake of radioactive material, assuming them to be more limiting. It appears that modest effort to reduce external radiation levels in these facilities may achieve a significant reduction in both average and collective doses.

Figure 6 displays the composite distribution of personnel monitoring results for the voluntary one-time submission for 1975 and compares it with a composite of the data submitted pursuant to §20.407 of 10 CFR Part 20 for that year. The latter licensees are found to involve higher average individual doses, and the fraction of collective dose contributed by individuals

receiving more than 1.5 rems is about twice that which would be consistent with the reference distribution. However, the collective dose represented by the voluntary data is about one-half (22,900/51,900) of the total collective dose, and about three-fourths (245,500/326,000) of the individuals monitored by NRC licensees were involved in activities not currently subject to the requirement for submission of an annual statistical summary report of monitoring data.

Figures 7 through 11 present the data submitted for 1975 by the four categories of licensees reporting pursuant to existing §20.407 of 10 CFR Part 20. They have been reported previously (Refs. 2,3,4,5,6,7) and are presented in this report to facilitate comparison with the data obtained from other categories of licensees. They are also presented to indicate how the data may be used to identify trends in personnel monitoring data.

The log-probability plots in Figure 7 for power reactors indicate a distinct shift of the distribution of doses between 1973 and 1974. However, the collective dose remained nearly constant. The shift was achieved by the use of significantly larger numbers of individuals (44,795 in 1973 and 66,044 in 1974) to accomplish the work.* This shift may reflect effort to maintain exposures as low as is reasonably achievable (ALARA). Such effort is also indicated by the departure from linearity of the log-probability plot. However, during 1975 the large increase in collective dose and the use of an intermediate number of workers (54,763) increased the average individual dose and shifted the distribution closer to that of 1973. Data for 1971 and 1972 (involves only doses exceeding 1.25 rems that were required to be reported at that time) are not shown in Figure 7, but would fall between the plots for 1973 and 1974. Each of these distributions has an Ω value equal to or greater than 2.

Figure 8, relating to industrial radiography, indicates a gradual decrease in average dose and displacement of the distribution plots from 1973 through 1975. The plots for 1971 and 1972 (doses equal to or greater than 1.25 rems) are not shown but would fall between those for 1973 and 1974. The linearity of the plots above 2 rems suggest two populations of workers, one working within the limit of 5 rems per year and another working within the 12 rems per year (3 rems per calendar quarter and the 5(N - 18) formula) historically recommended by the ICRP and permitted pursuant to §20.101(b) of 10 CFR Part 20. Each of the distributions has an Ω value near 1.7.

Figure 9, relating to both fuel processing and reprocessing, indicates a gradual decrease in doses from 1971 to 1973. The decrease is largely due to a decreasing contribution from reprocessing activities. Consideration of the experience of fuel processing alone (not shown in Figure 9) reflects a gradual increase in the number of individuals involved and in both average and collective doses from 1971 through 1975. The projected tenfold increase in fuel fabrication activities by the year 2000 emphasizes the need to maintain exposures ALARA. As noted with respect to source material licensees (Figure 5), it is believed that the radiation control

*It is likely that the use of larger numbers of workers resulted in a higher collective dose than might otherwise have been experienced. Some dose is received during entry, orientation to the work, and exit from the area as well as during actual performance of the work. Such dose may be considered unprofitable, counterproductive, or even unnecessary if the task can be performed with fewer workers.

programs in fuel processing plants have been based on factors associated with the intake of radioactive material. Modest efforts to reduce external radiation levels in these facilities may achieve a significant reduction in both average and collective doses.

Figure 10 relates to the licensees involved in manufacturing and distribution of byproduct material who are required to report pursuant to §20.407 of 10 CFR Part 20. The data indicate a gradual increase in the average individual doses and shifting of the distribution. Plots of data for 1971 and 1972 (doses equal to or greater than 1.25 rems) would fall very close to the plot for 1973. Fewer individuals were involved in 1974 and the collective dose was smaller. The curvature of the plots may reflect several major subdistributions of work involved. However, the curvature of the upper reaches of the plot probably indicates considerable effort to keep doses within regulatory limits. Further, the slight upward curvature of the lower reaches of the plot may reflect some rotation of job assignments, flattening the overall distribution. The Ω values have remained greater than 2 (see Figure 3 and related observations).

Figure 11 presents plots of the annual composites of the data submitted pursuant to §20.407 of 10 CFR Part 20. The composite data are heavily influenced by the contribution from power reactor licensees, which involved between 65% and 75% of both the number of individuals and the collective dose. (See Figure 7 and associated observations.) Inspection of Figures 7 through 11 indicate that average individual doses for the four categories of licensees involved have remained within a narrow range (0.23 to 0.4 rem) and Ω values have remained between 1.64 and 2.29. Thus, individuals in these four categories experience a very comparable risk of radiation dose. The collective dose for each of the categories is proportional to the number of individuals involved.

RESERVATIONS REGARDING THE DATA

The reader is cautioned that any conclusions drawn from these data must be conditioned by a number of reservations. The data are obtained from routine personnel monitoring programs and are not directly suitable for interpretation as dose equivalent to the individuals involved. Among the factors involved are the possibility that the dosimeter was exposed while not being worn by the individual to whom it was assigned, the possiblity that the exposure incident on the dosimeter was only part of that received by a major portion of the body of the wearer because of collimation of the radiation, local shielding, etc., and the possibility that the radiation was incident upon the body in such a manner that the monitoring device recorded exit dose rather than the highest dose received at any point on the body. There are inaccuracies in the estimation of the dose received by the dosimeter itself. Other reservations must be introduced for potential bias involving the fraction of licensees in each category that responded to the request for voluntary one-time submission of the data. Small licensees and very large licensees who have resorted to computer programs for handling their records may have been more likely to respond than intermediate-size licensees who still process their data manually. It is not known to what extent the monitoring experience of these licensees parallels that of the others. There is the possibility that the data may be biased because licensees that have well-controlled radiation programs and who are enjoying relatively low radiation doses may have been more likely to report voluntarily than those who are experiencing relatively high doses. While licensees have been placed in a large number of categories according to the type of licensed

program, a variety of operations is conducted by some licensees, including the use of X-ray equipment and other sources of radiation not regulated by the NRC. The data contain the monitoring results obtained from visitors and other individuals who would not have been required to be monitored. The number of such individuals will vary with the administrative policy of the licensee involved and will shift the average dose calculated from the data. However, as has been demonstrated (Ref. 4), the number of these individuals will have little impact on the collective dose attributed to the licensed activity in question or on the log-probability plot of the distributions of estimated doses.

The NRC staff recognizes the diversity of programs conducted by licensees but believes that there is sufficient basis for comparison of exposure experience among types of licensees and among licensees within each type. The staff believes that adequate personnel monitoring measurements sufficiently characterize the radiation environment in which individuals work to provide an adequate basis for the evaluation of radiation protection and desires to be informed of the estimated doses being recorded in order to permit evaluation of the effectiveness of the NRC regulatory program.

COST OF REPORTING

In keeping with its policy of assessing the value and impact of proposed changes in the regulatory systems, the August 25, 1976, letter also invited licensees to provide an estimate of their effort in man-hours and the total cost in preparing an annual statistical summary report of their personnel monitoring data. The distributions of 172 responses regarding man-hours of effort and 125 responses regarding cost indicate median commitments of 0.046 man-hours and $0.65, respectively, per monitored individual (see Figures 12 and 13).

Application of these median effort and cost estimates to the 81,000 individuals monitored by licensees currently required to report pursuant to §20.407 of 10 CFR Part 20 indicate a licensee commitment of about 3,700 man-hours or $52,700. Extension of the reporting requirement to all NRC licensees could add a licensee commitment for the 245,500 individuals monitored of 11,300 man-hours or $159,600, an average of 1.4-man-hours or about $20 per licensee. However, because these estimates of effort or cost commitment were provided by licensees who had never before prepared such an annual report, the cost to licensees under an on-going reporting requirement probably would be less.

The cost to the NRC of the collection, computerization, and analysis of the data currently being received under §20.407 of 10 CFR Part 20 annually involves about 1.5 man-years of effort plus about $25,000 in computer-related costs. Extension of the reporting requirement to all NRC licensees would not require additional NRC staff but would increase the computer-related costs to about $30,000.

REFERENCES

1. Brooks, B. G., "Seventh Annual Occupational Radiation Exposure Report," 1974, United States Nuclear Regulatory Commission, NUREG-75/108 (1975).

2. Brooks, B. G., "Eighth Annual Occupational Radiation Exposure Report," 1975, United States Nuclear Regulatory Commission, NUREG-0119.

3. Brodsky, A., Specht, R. P., Brooks, B. G., et al., "Log-Normal Distributions of Occupational Exposure in Medicine and Industry," presented at the 9th Midyear Symposium of the Health Physics Society, 1976.

4. United Nations, "Report of the Scientific Committee on the Effects of Atomic Radiation 1977," General Assembly Official Records: Thirty-Second Session, Supplement No. 40, United Nations, New York.

5. Murphy, T. D., "A Compilation of Occupational Radiation Exposure From Light-Water Cooled Nuclear Power Plants 1969-1973," United States Nuclear Regulatory Commission, WASH-1311, May 1974.

6. Murphy, T. D., Hinson, C. S., "Occupational Radiation Exposure At Light-Water Cooled Power Reactors 1969-1974," United States Nuclear Regulatory Commission, NUREG-75/032, June 1975.

7. Murphy, T. D., Dayem, N. J., Bland, J. S., Pasciak, W. J., "Occupational Radiation Exposure at Light-Water Cooled Power Reactors 1969-1975," United States Nuclear Regulatory Commission, NUREG-0109, August 1976.

TABLE 1
SUMMARY OF 1975 VOLUNTARY MONITORING DATA

Category	Fraction Reporting	Number of Licensees Who Monitored	Number of Individuals Monitored	Average Dose, Rems	Number of Individuals With Measurable Doses	Average Measurable Dose, Rems	Collective Dose Reported, Man-Rems	Average Collective Dose Per Licensee, Man-Rems	Extrapolated Number of Individuals Monitored[a]	Extrapolated Collective Dose,[b] Man-Rems
Byproduct Material										
Academic Broad	8/22	8	1,927	0.01	207	0.10	21.11	2.64	5,300	60
Academic Other	79/476	54	3,609	0.03	970	0.11	103.54	1.31	21,700	620
Instit. Broad Med.	40/94	40	14,228	0.07	5,354	0.18	975.98	24.40	33,400	2,290
Instit. Other Med.	345/1355	342	9,643	0.18	6,180	0.28	1,750.18	5.07	37,900	6,870
Private Practice	73/701	64	486	0.28	392	0.35	137.31	1.88	4,700	1,320
Teletherapy	46/470	46	1,716	0.15	927	0.29	264.73	5.76	17,500	2,700
Other Medical	17/103	14	356	0.13	168	0.27	46.01	2.71	2,200	280
Radiopharm. Dist.	3/30	3	25	0.08	9	0.23	2.10	0.70	250	20
Pacemakers Instit.	0/8									
Pacemakers Individ.	0/4									
Well Logging	14/63	14	1,514	0.44	1,328	0.50	666.11	47.58	6,800	3,000
Other Meas. Systems	278/2109	121	2,594	0.06	1,053	0.14	147.31	0.53	19,700	1,120
Marketing Broad	11/62	8	703	0.05	140	0.26	36.31	3.30	4,000	200
Marketing Other	48/244	39	1,195	0.07	293	0.28	82.39	1.72	6,100	420
Gen. Lic. Dist.	2/57	1	8	0.13	8	0.13	1.05	0.53	230	30
Exempt Quant. Dist.	4/44	2	103	0.03	50	0.07	3.58	0.90	1,130	40
Exempt Watch Dist.	5/64	1	11	0.06	11	0.06	0.68	0.14	140	10
Other Exempt Dist.	7/84	6	232	0.01	49	0.06	3.03	0.43	2,790	35
Nuclear Laundry	1/5	1	4	0.00					20	
Leak Test	3/28	2	6	0.06	4	0.08	0.33	0.11	60	3
Waste Disposal - Burial	4/4	4	65	1.24	64	1.26	80.63	20.16	65	81
Waste Disposal - Other	2/9	2	8	0.006	1	0.05	0.05	0.03	40	0.2
Power Sources	0/1									
Irradiator <10,000 Ci	3/164	2	26	0.03	5	0.17	0.83	0.28	1,420	50
Irradiator >10,000 Ci	3/55	3	134	0.003	1	0.38	0.38	0.13	2,460	7
R & D Broad	21/83	20	5,802	0.03	1,250	0.14	180.36	8.59	22,900	710
R & D Other	88/435	69	2,298	0.02	724	0.08	54.30	0.62	11,400	270
Civil Defense	10/129	8	682	0.04	553	0.05	28.36	2.84	8,800	370
Byproduct Export	0/56									
Transport Large Qty.	0/3									
Transport Type B	1/1	1	190	0.16	110	0.28	30.47	30.47	190	30
Source Material										
U Mills	7/17	7	437	0.38	404	0.41	166.05	23.72	1,060	400
Other U <150 kg	3/58	2	19	0.00					370	
Other U >150 Kg	8/320	8	149	0.12	108	0.17	18.56	2.32	5,960	740
UF_6 Production	2/2	2	522	0.14	330	0.22	73.56	36.78	520	70
Source Mtl. Export	1/48	1	50	0.02	22	0.05	1.10	1.10	2,400	50
Source Mtl. Import	0/4									

Continued....

Table 1 (Continued)

Category	Fraction Reporting	Number of Licensees Who Monitored	Number of Individuals Monitored	Average Dose, Rems	Number of Individuals With Measurable Doses	Average Measurable Dose, Rems	Collective Dose Reported, Man-Rems	Average Collective Dose Per Licensee, Man-Rems	Extrapolated Number of Individuals Monitored[a]	Extrapolated Collective Dose,[b] Man-Rems
Special Nuclear Material										
Other Pu Uses R&D	0/3									
Other U Uses R&D	1/22	1	154	0.02	15	0.17	2.53	2.53	3,390	60
Unencapsulated SNM	2/29	2	204	0.11	14	1.54	21.59	10.80	2,960	310
Neutron Sources	18/308	9	247	0.02	45	0.09	4.08	0.23	4,230	70
Power Sources	0/4									
Other SNM Sources	5/60	4	203	0.05	77	0.13	9.79	1.96	2,440	120
Pacemakers Instit.	0/91									
Pacemakers Individ.	1/7	0								
U Sources	3/48	3	408	0.001	8	0.07	0.53	0.18	6,530	8
Fuel Storage	1/10	1	13	0.69	13	0.69	9.00	9.00	130	90
SNM Storage Only	1/2	1	4	0.01	1	0.05	0.05	0.05	8	0.1
SNM Import	0/12									
SNM Export	1/156	1	6	0.00	0				940	
Transport Irr. Fuel	0/2									
Transport Unirr. Fuel	0/2									
Transport Large Quant.	0/3									
Test Reactors	1/2	1	7	0.05	7	0.05	0.35	0.35	14	0.7
Research Reactors	3/66	3	152	0.12	120	0.16	18.98	6.33	3,350	420
[c]Power Reactors	54/54	54	54,763	0.39	28,034	0.76	21,269.72	393.88	54,763	21,270
[c]Radiographers	291/320	291	9,178	0.31	4,693	0.60	2,795.94	9.61	10,100	3,080
[c]Fuel Proc & Reproc	24/24	24	11,614	0.27	5,602	0.57	3,175.30	132.30	11,614	3,175
[d]Manufacture & Dist.	19/23	19	3,367	0.35	1,859	0.64	1,188.17	62.54	4,100	1,440

[a](Extrapolated Number of Individuals Monitored) = (Individuals Monitored)/(Fraction Reporting)

[b](Extrapolated Collective Dose) = (Reported Collective Dose)/(Fraction Reporting)

Note: The effect on these extrapolations of the licensees who did not monitor is canceled by appearance in both the numerator and denominator of the Fraction Reporting.

[c]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

[d]Subset of "Marketing Broad" and "Marketing Other" meeting the criteria in §20.407(a)(4) of 10 CFR Part 20.

TABLE 2
1975 MONITORING DATA BY LICENSEE FUNCTIONAL GROUP
(EXTRAPOLATED TO ALL LICENSEES IN GROUP)

Licensee Functional Grouping	Number of Individuals Monitored	Collective Dose, Man-Rems	Average Dose Per Individual, Rems
Academic	27,000	680	0.03
Medical	95,700	13,500	0.14
Marketing	14,600	760	0.05
R & D	34,300	980	0.03
Byproduct Material	211,200	20,540	0.10
Source Material	10,300	1,260	0.12
Special Nuclear Material	20,630	660	0.03
Research & Test Reactors	3,400	420	0.12
Power Reactors[a]	54,760	21,270	0.39
Industrial Radiographers[a]	10,100	3,080	0.31
Fuel Processing & Reprocessing[a]	11,610	3,175	0.27
Manufacturing & Distribution[b]	4,100	1,440	0.35

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

[b]Subset of "Marketing Broad" and "Marketing Other" meeting the criteria in §20.407(a)(4) of 10 CFR Part 20.

TABLE 3
DISTRIBUTION OF ESTIMATED DOSES - 1975 VOLUNTARY DATA

Category of Licensee	Total No. Monitored	Exposure Ranges (Rems)																	
		Less Than Measurable	Meas'ble 0.10	0.10 0.25	0.25 0.50	0.50 0.75	0.75 1.0	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12+
Byproduct Material																			
Academic Broad	1927	1720	157	35	11	2	2												
Academic Other	3609	2639	781	127	34	13	5	8	2										
Instit. Broad Med.	14228	8874	3451	1016	502	160	85	106	25	4	2	1	2						
Instit. Other Med.	9643	3463	3094	1402	834	361	190	200	52	22	16	2	4	0	1	0	2		
Private Practice	486	94	166	90	67	27	12	19	4	3	0	2							
Teletherapy	1716	789	539	158	111	48	16	30	14	5	6								
Other Medical	356	188	101	24	17	12	5	6	2	0	1								
Radiopharm. Dist.	25	16	3	4	0	2													
Pacemakers Instit.																			
Pacemakers Individ.																			
Well Logging	1514	186	387	315	249	128	82	117	23	19	4	1	1	1	0	1			
Other Meas. Systems	2594	1541	704	197	103	36	8	3	2										
Marketing Broad	703	563	77	29	16	5	2	11											
Marketing Other	1195	902	177	58	21	11	7	12	3	1	3								
Gen. Lic. Dist.	8	0	6	0	2														
Exempt Quant. Dist.	103	53	45	4	0	1													
Exempt Watch Dist.	11	0	10	1															
Other Exempt Dist.	232	183	46	2	1														
Nuclear Laundry	4	4																	
Leak Test	6	2	3	1															
Waste Disposal - Burial	65	1	9	11	8	6	4	8	9	7	2								
Waste Disposal - Other	8	7	1																
Power Sources																			
Irradiator <10,000 Ci	26	21	4	0	0	1													
Irradiator >10,000 Ci	134	133	0	0	1														
R & D Broad	5802	4552	1025	117	49	18	12	14	6	8	1								
R & D Other	2298	1574	651	50	16	4	0	3											
Civil Defense	682	129	551	1	0	1													
Byproduct Export																			
Transport Large Quant.																			
Transport Type B	190	80	43	21	25	15	5	1											
Source Material																			
U Mills	437	33	123	88	86	44	22	38	2	1									
Other U <150 kg	19	19																	
Other U >150 kg	149	41	78	13	10	0	3	4											
UF_6 Production	522	192	118	128	49	20	13	2											
Source Mtl. Export	50	28	22																
Source Mtl. Import																			

Continued...

Table 3 (Continued)

Category of Licensee	Total No. Monitored	Exposure Ranges (Rems)																	
		Less Than Measurable	Meas'ble 0.10	0.10 0.25	0.25 0.50	0.50 0.75	0.75 1.0	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12+
Special Nuclear Material																			
Other Pu Uses R&D																			
Other U Uses R&D	154	139	4	9	2														
Unencapsulated SNM	204	190	3	1	1	0	1	3	2	3									
Neutron Sources	247	202	32	12	1														
Power Sources																			
Other SNM Sources	203	126	59	9	5	3	0	1											
Pacemakers Instit.																			
Pacemakers Individ.																			
U. Sources	408	400	7	1															
Fuel Storage	13	0	0	0	2	8	2	1											
SNM Storage Only	4	3	1																
SNM Import																			
SNM Export	6	6																	
Transport Irr. Fuel																			
Transport Unirr. Fuel																			
Transport Large Quant.																			
Test Reactors	7	0	7																
Research Reactors	152	32	39	73	4	3	1												
[a]Power Reactors	54763	26729	10606	4081	2948	1778	1384	3982	1873	692	4[illegible]	169	60	24	12	0	1		
[a]Radiographers	9178	4485	1811	813	614	346	263	538	171	64	35	21	8	1	3	1	2	1	1
[a]Fuel Proc & Reproc	11614	6012	2019	1115	1029	440	253	393	157	77	40	30	11	9	14	15			
[b]Manufacture & Dist.	3367	1508	644	532	214	88	67	140	65	43	39	11	12	3	0	1			

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

[b]Subset of "Marketing Broad" and "Marketing Other" meeting the criteria in §20.407(a)(4) of 10 CFR Part 20.

TABLE 4
EXTRAPOLATED TOTAL COLLECTIVE DOSE BY CATEGORY OF LICENSEE (MAN-REMS)

[a]Power Reactors	21,270
Instit. Other Medical	6,880
[a]Fuel Proc. & Reproc.	3,175
[a]Radiographers	3,080
Well Logging	3,000
Teletherapy	2,700
Instit. Broad Medical	2,290
[a]Manufacture & Dist.	1,440
Private Practice	1,320
Other Meas. Systems	1,120
Other U >150 kg	740
R & D Broad	710
Academic Other	620
Marketing Other	420
Research Reactors	420
U Mills	400
Civil Defense	370
Unencapsulated SNM	310
Other Medical	280
R & D Other	270
Marketing Broad	200
Other SNM Sources	120
Fuel Storage	90
Waste Disposal - Burial	81
UF_6 Production	70
Neutron Sources	70
Academic Broad	60
Other U Uses R & D	60
Source Mtl. Export	50
Irradiator <10,000 Ci	50
Exempt Quant. Dist.	40
Other Exempt Dist.	35
Gen. Lic. Dist.	30
Transport Type B	30
Radiopharm. Dist.	20
Exempt Watch Dist.	10
U Sources	8
Irradiator >10,000 Ci	7
Leak Test	3
Test Reactors	0.7
Waste Disposal Other	0.2
SNM Storage Only	0.1

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

TABLE 5
AVERAGE COLLECTIVE DOSE PER LICENSEE IN A GIVEN CATEGORY
(MAN-REMS)

[a]Power Reactors	394
[a]Fuel Proc. & Reproc.	132
[a]Manufacture & Dist.	62.5
Well Logging	47.6
UF_6 Production	36.8
Transport Type B	30.5
Instit. Broad Medical	24.4
U Mills	23.7
Waste Disposal - Burial	20.2
Unencapsulated SNM	10.8
[a]Radiographers	9.6
Fuel Storage	9.0
R & D Broad	8.6
Research Reactors	6.3
Teletherapy	5.8
Instit. Other Medical	5.1
Marketing Broad	3.3
Civil Defense	2.8
Other Medical	2.7
Academic Broad	2.6
Other U Uses R & D	2.5
Other U >150 kg	2.3
Other SNM Sources	2.0
Private Practice	1.9
Marketing Other	1.7
Academic Other	1.3
Source Mtl. Export	1.1
Exempt Quant. Dist.	.9
Radiopharm. Dist.	.7
R & D Other	.6
Other Meas. Systems	.5
Gen. Lic. Dist.	.5
Other Exempt Dist.	.4
Test Reactors	.4
Irradiator <10,000 Ci	.3
Neutron Sources	.2
U Sources	.2
Exempt Watch Dist.	.1
Irradiator >10,000 Ci	.1
Leak Test	.1
SNM Storage Only	.1
Waste Disposal Other	.03

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

TABLE 6
AVERAGE INDIVIDUAL DOSE BY CATEGORY

Category of Licensee	Average Dose, Rems	Average Measurable Dose, Rems
Waste Disposal - Burial	1.24	1.26
Fuel Storage	0.69	0.69
Well Logging	0.44	0.50
[a]Power Reactors	0.39	0.76
U Mills	0.38	0.41
[a]Manufacture & Dist.	0.35	0.64
[a]Radiographers	0.31	0.60
Private Practice	0.28	0.35
[a]Fuel Proc. & Reproc.	0.27	0.57
Instit. Other Medical	0.18	0.28
Transport Type B	0.16	0.28
Teletherapy	0.15	0.29
UF_6 Production	0.14	0.22
Other Medical	0.13	0.27
Gen. Lic. Dist.	0.13	0.13
Research Reactors	0.13	0.16
Other U >150 kg	0.12	0.17
Unencapsulated SNM	0.11	1.54
Radiopharm. Dist.	0.08	0.23
Instit. Broad Medical	0.07	0.18
Marketing Other	0.07	0.28
Other Meas. Systems	0.06	0.14
Exempt Watch Dist.	0.06	0.06
Leak Test	0.06	0.08
Marketing Broad	0.05	0.26
Other SNM Sources	0.05	0.13
Test Reactors	0.05	0.05
Civil Defense	0.04	0.05
Exempt Quant. Dist.	0.03	0.07
Academic Other	0.03	0.11
Irradiator <10,000 Ci	0.03	0.17
R & D Broad	0.03	0.14
R & D Other	0.02	0.08
Source Mtl. Export	0.02	0.05
Other U Uses R & D	0.02	0.17
Neutron Sources	0.02	0.09
Academic Broad	0.01	0.10
Other Exempt Dist.	0.01	0.06
SNM Storage Only	0.01	0.05
Waste Disposal Other	0.006	0.05
Irradiator >10,000 Ci	0.003	0.38
U Sources	0.001	0.07

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

TABLE 7
AVERAGE INDIVIDUAL DOSE, EXTRAPOLATED COLLECTIVE DOSE, AND Ω
1975 VOLUNTARY DATA

Category Of Licensee	Average Individual Dose ($\bar{D}$), Rems	Extrapolated Collective Dose (S), Man-Rems	Ω[a]
Byproduct Material			
Academic Broad	0.01	60	0.0
Academic Other	0.03	620	0.34
Instit. Broad Med	0.07	2,290	0.61
Instit. Other Med	0.18	6,880	0.92
Private Practice	0.28	1,320	1.08
Teletherapy	0.15	2,700	1.24
Other Medical	0.13	280	0.98
Radiopharm. Dist.	0.08	20	0.0
Pacemakers Instit.			
Pacemakers Individ.			
Well Logging	0.44	3,000	1.25
Other Meas. Systems	0.06	1,120	0.16
Marketing Broad	0.05	200	0.73
Marketing Other	0.07	420	1.32
Gen. Lic. Dist.	0.13	30	0.0
Exempt Quant. Dist.	0.03	40	0.0
Exempt Watch Dist.	0.06	10	0.0
Other Exempt Dist.	0.01	35	0.0
Nuclear Laundry	0.00		
Leak Test	0.06	3	0.0
Waste Disposal Burial	1.24	81	2.48
Waste Disposal Other	0.006	0.2	0.0
Power Sources			
Irradiator <10,000 Ci	0.03	50	0.0
Irradiator >10,000 Ci	0.003	7	0.0
R & D Broad	0.03	710	1.04
R & D Other	0.02	270	0.13
Civil Defense	0.04	370	0.0
Byproduct Export			
Transport Large Quant.			
Transport Type B	0.16	30	0.08
Source Material			
U Mills	0.38	400	0.72
Other U <150 kg	0.00		
Other U >150 kg	0.12	740	0.52
UF_6 Production	0.14	70	0.07
Source Mtl. Export	0.02	50	0.0
Source Mtl. Import			

Continued...

[a] Ω, a dimensionless quantity, is the ratio of the fraction of the collective dose due to annual doses above 1.5 rads for the observed distribution to the fraction for the UNSCEAR reference distribution (Ref. 4). For any observed distribution $\Omega = 3.23S_{1.5}/S$.

Table 7 (Continued)

Category Of Licensee	Average Individual Dose ($\bar{D}$), Rems	Extrapolated Collective Dose (S), Man-Rems	Ω[a]
Special Nuclear Material			
Other Pu Uses R&D	0.02	60	0.0
Other U Uses R&D	0.11	310	2.66
Unencapsulated SNM	0.02	70	0.0
Neutron Sources			
Power Sources	0.05	120	0.25
Other SNM Sources			
Pacemakers Instit.			
Pacemakers Individ.	0.001	8	0.0
U Sources	0.69	90	0.27
Fuel Storage	0.01	0.1	0.0
SNM Storage Only			
SNM Import	0.00		
SNM Export			
Transport Irr. Fuel			
Transport Unirr. Fuel			
Transport Large Quant.			
Test Reactors	0.05	0.7	0.0
Research Reactors	0.12	420	0.0

TABLE 8
AVERAGE INDIVIDUAL DOSE, EXTRAPOLATED COLLECTIVE DOSE, AND Ω
1973-1975 10 CFR §20.407 DATA[a]

Category Of Licensee	Average Individual Dose ($\bar{D}$), Rems	Extrapolated Collective Dose (S), Man-Rems	Ω[b]
Power Reactors			
1973	0.32	14,337	2.29
1974	0.23	14,083	2.00
1975	0.39	21,270	2.07
Industrial Radiographers			
1973	0.40	3,630	1.75
1974	0.33	3,030	1.64
1975	0.31	3,080	1.71
Fuel Processing & Reprocessing			
1973	0.23	2,400	1.81
1974	0.25	2,739	1.96
1975	0.27	3,175	1.74
Manufacturing & Distribution			
1973	0.28	1,210	2.09
1974	0.32	1,140	2.04
1975	0.35	1,440	2.08

[a] The four categories of licensees have been reporting pursuant to §20.407 of 10 CFR Part 20 in the statistical summary format since 1973. Prior reports included only those estimated doses in excess of 1.25 rems.

[b] Ω, a dimensionless quantity, is the ratio of the fraction of the collective dose due to annual doses above 1.5 rads for the observed distribution to the fraction for the UNSCEAR reference distribution (Ref. 4). For any observed distribution $\Omega = 3.23S_{1.5}/S$.

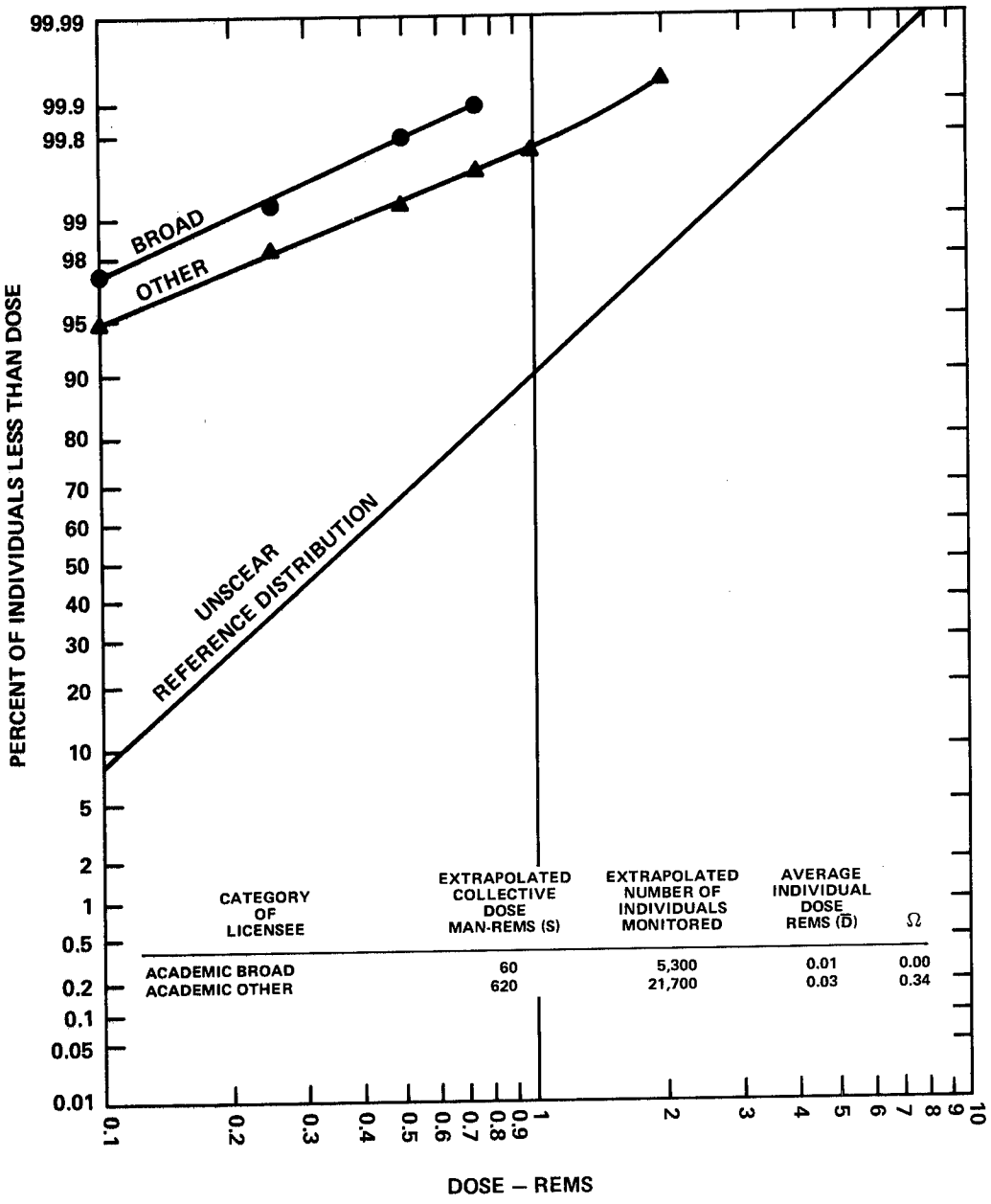
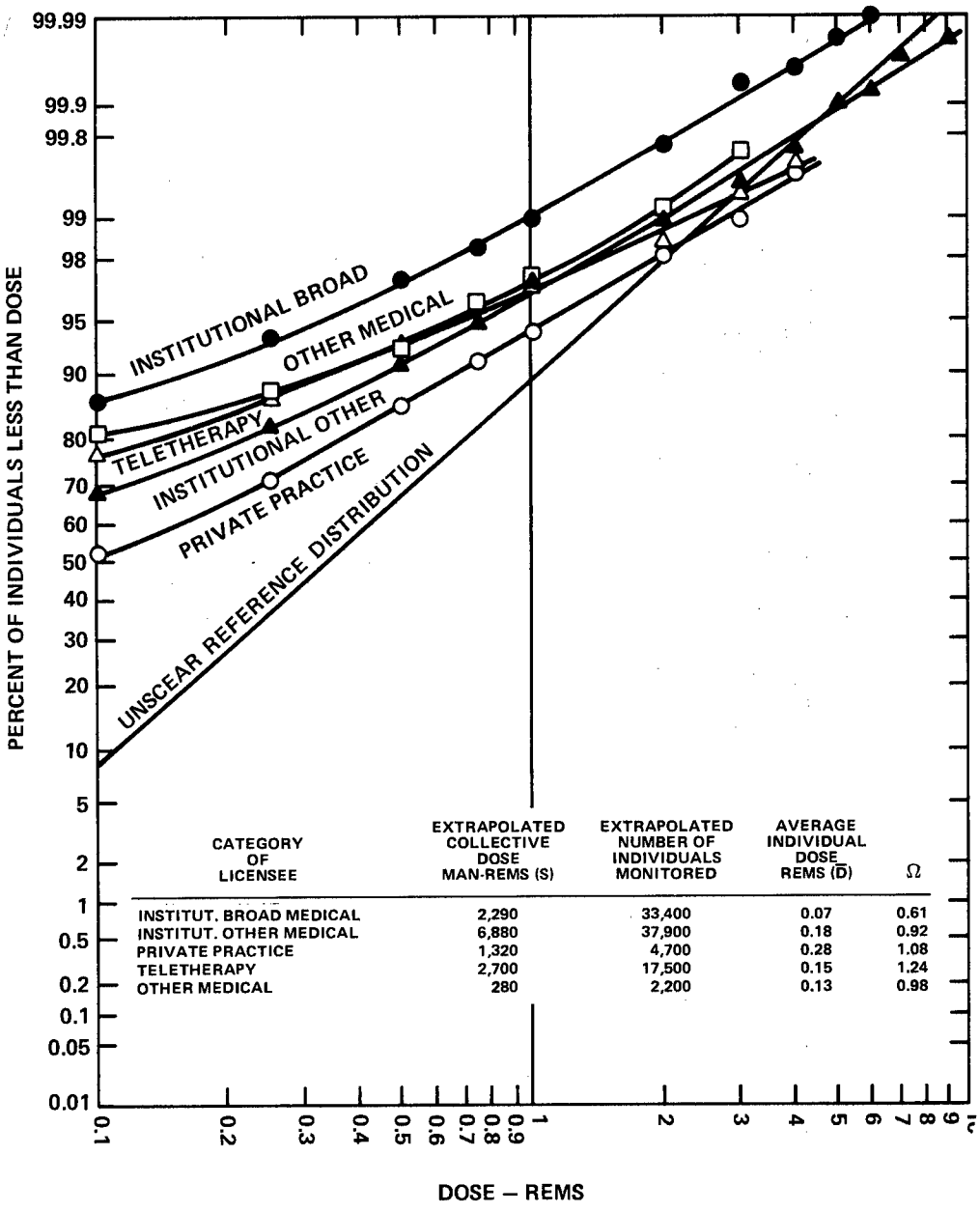
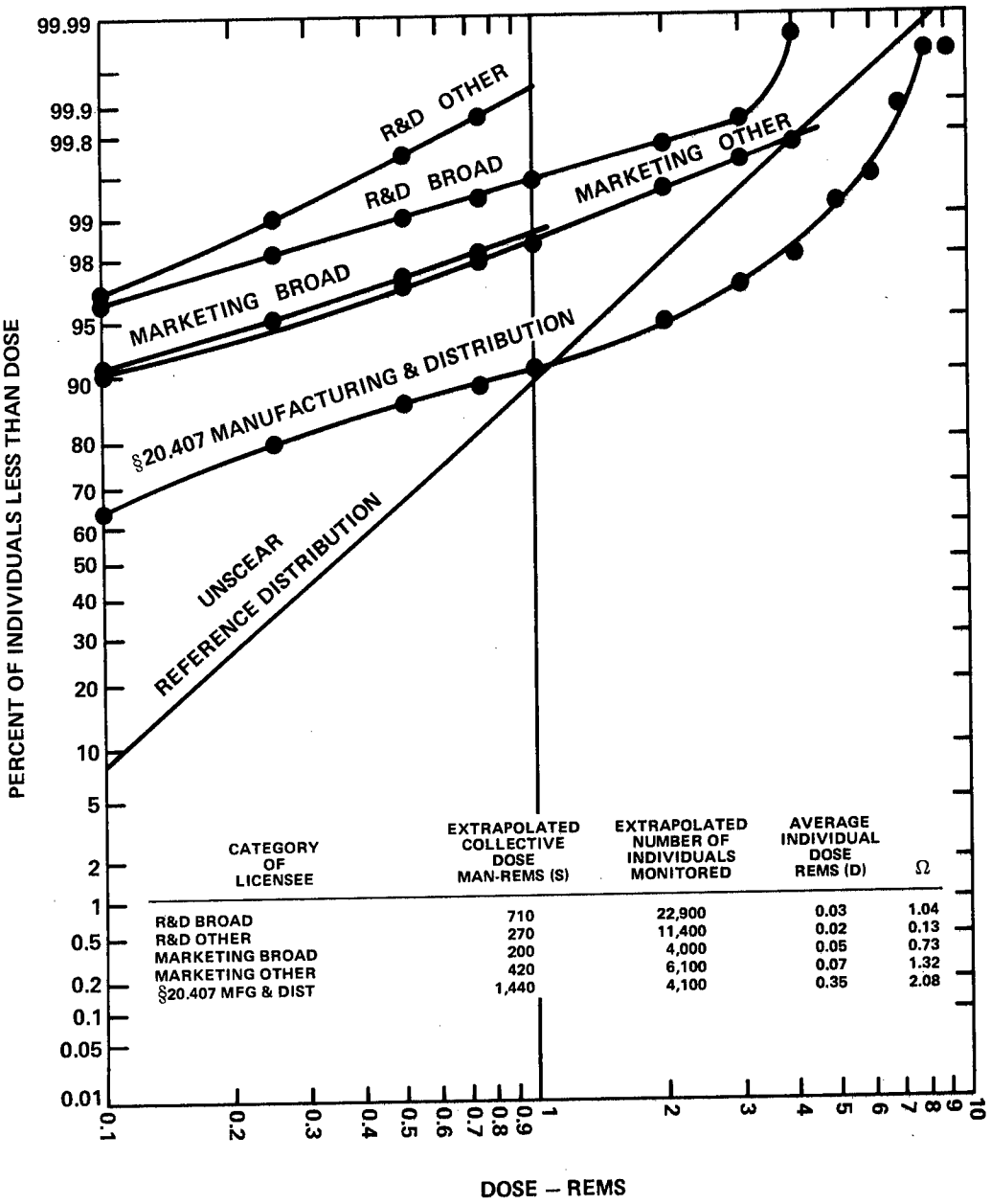


Figure 1. 1975 Voluntary Data - Academic Licensees



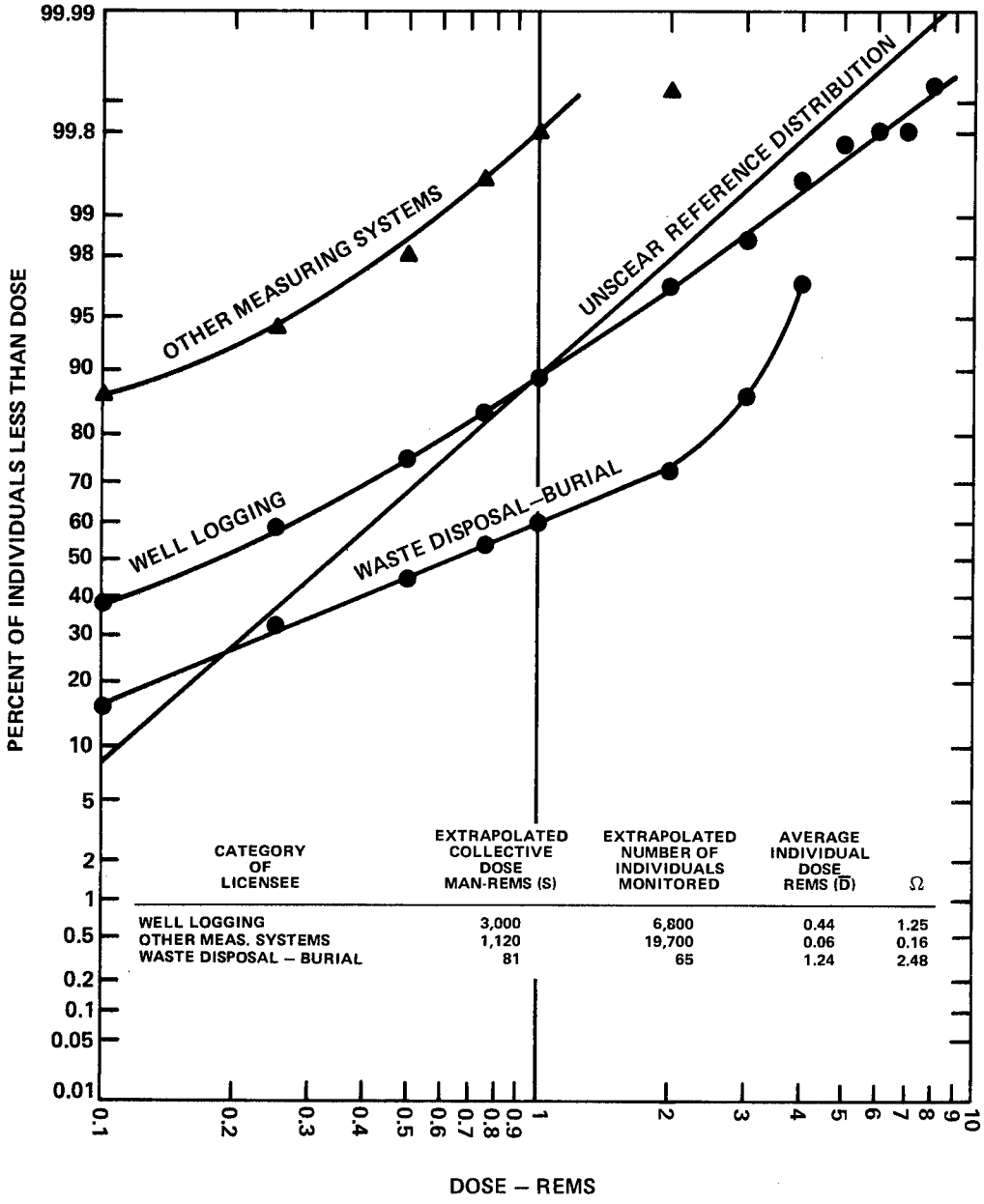
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS ($\bar{D}$)	Ω
INSTITUT. BROAD MEDICAL	2,290	33,400	0.07	0.61
INSTITUT. OTHER MEDICAL	6,880	37,900	0.18	0.92
PRIVATE PRACTICE	1,320	4,700	0.28	1.08
TELETHERAPY	2,700	17,500	0.15	1.24
OTHER MEDICAL	280	2,200	0.13	0.98

Figure 2. 1975 Voluntary Data - Medical Licensees



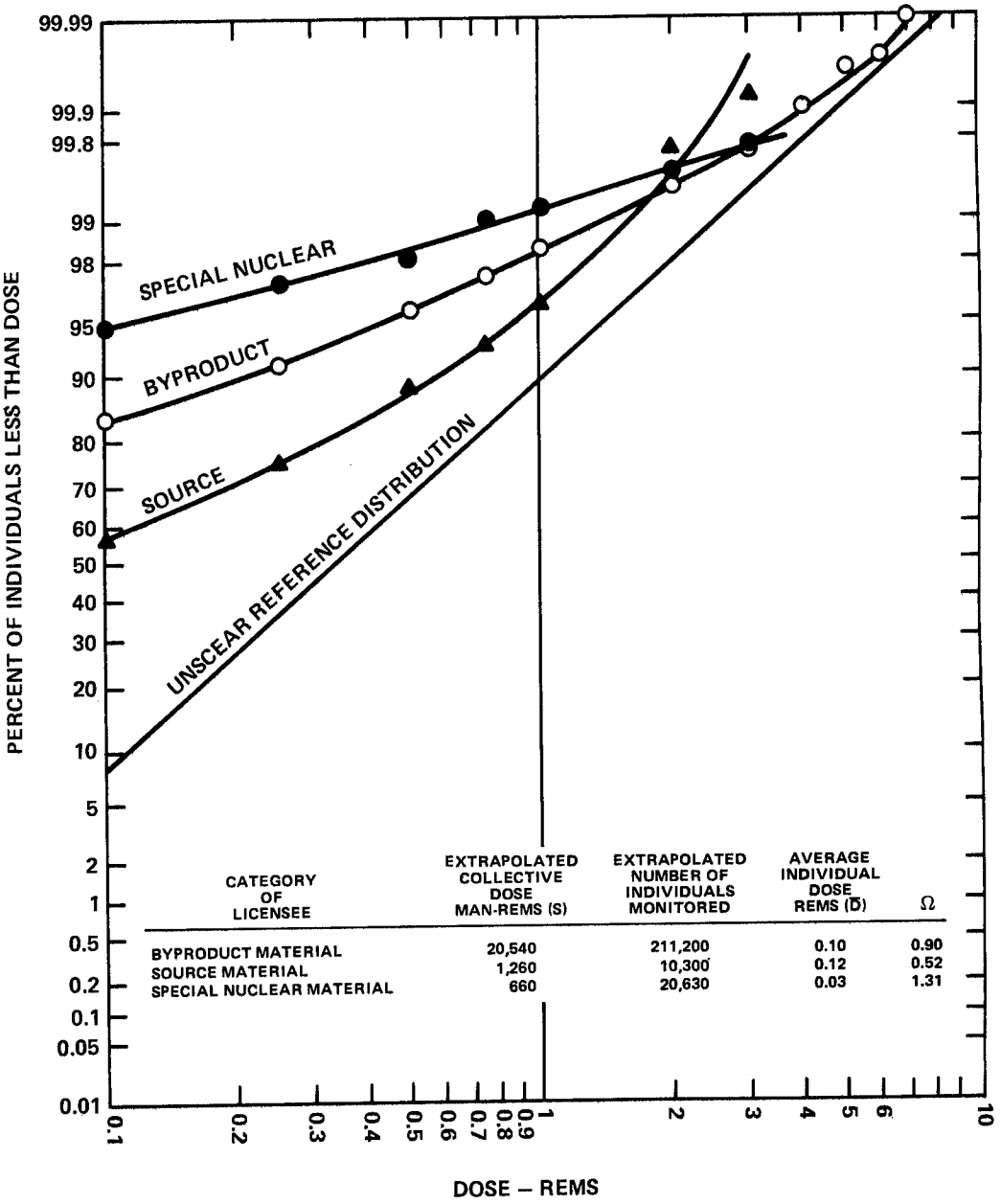
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS (D)	Ω
R&D BROAD	710	22,900	0.03	1.04
R&D OTHER	270	11,400	0.02	0.13
MARKETING BROAD	200	4,000	0.05	0.73
MARKETING OTHER	420	6,100	0.07	1.32
§20.407 MFG & DIST	1,440	4,100	0.35	2.08

Figure 3. 1975 Voluntary Data - R & D and Marketing Licensees



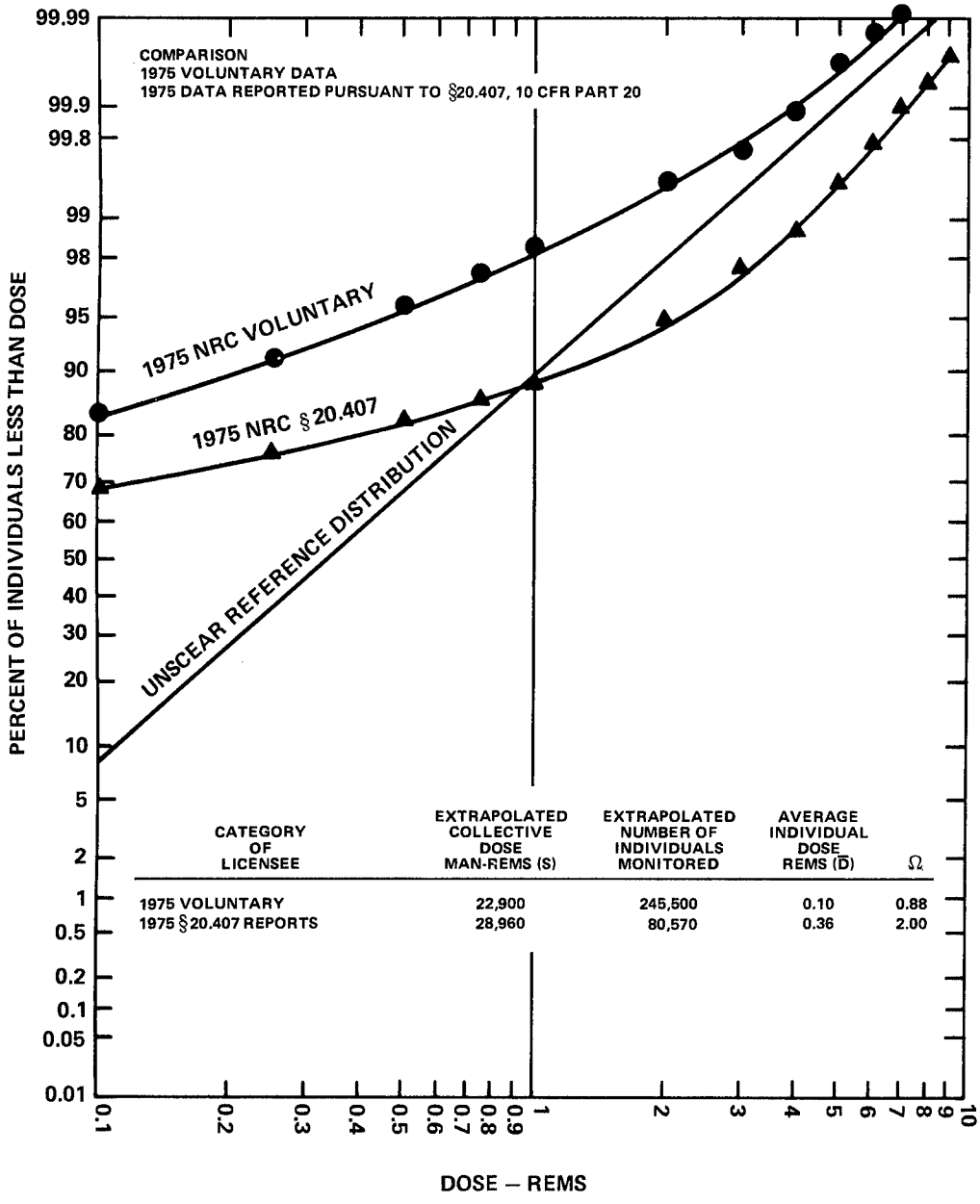
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS ($\bar{D}$)	Ω
WELL LOGGING	3,000	6,800	0.44	1.25
OTHER MEAS. SYSTEMS	1,120	19,700	0.06	0.16
WASTE DISPOSAL – BURIAL	81	65	1.24	2.48

Figure 4. 1975 Voluntary Data - Well Logging, Other Measurement Systems, and Waste Disposal - Burial Licensees



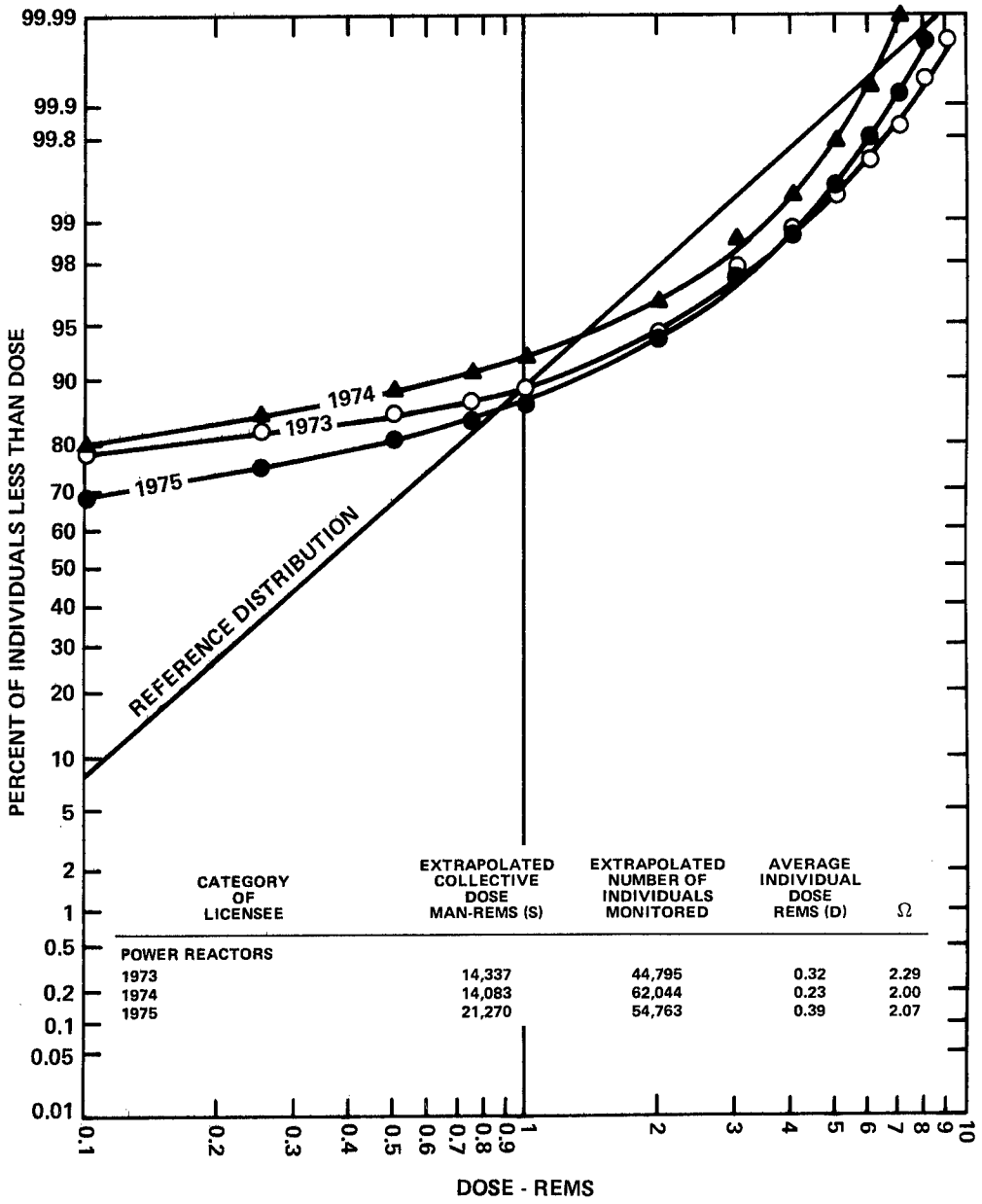
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS ($\bar{D}$)	Ω
BYPRODUCT MATERIAL	20,540	211,200	0.10	0.90
SOURCE MATERIAL	1,260	10,300	0.12	0.52
SPECIAL NUCLEAR MATERIAL	660	20,630	0.03	1.31

Figure 5. 1975 Voluntary Data - Byproduct, Source, and Special Nuclear Material Licensees



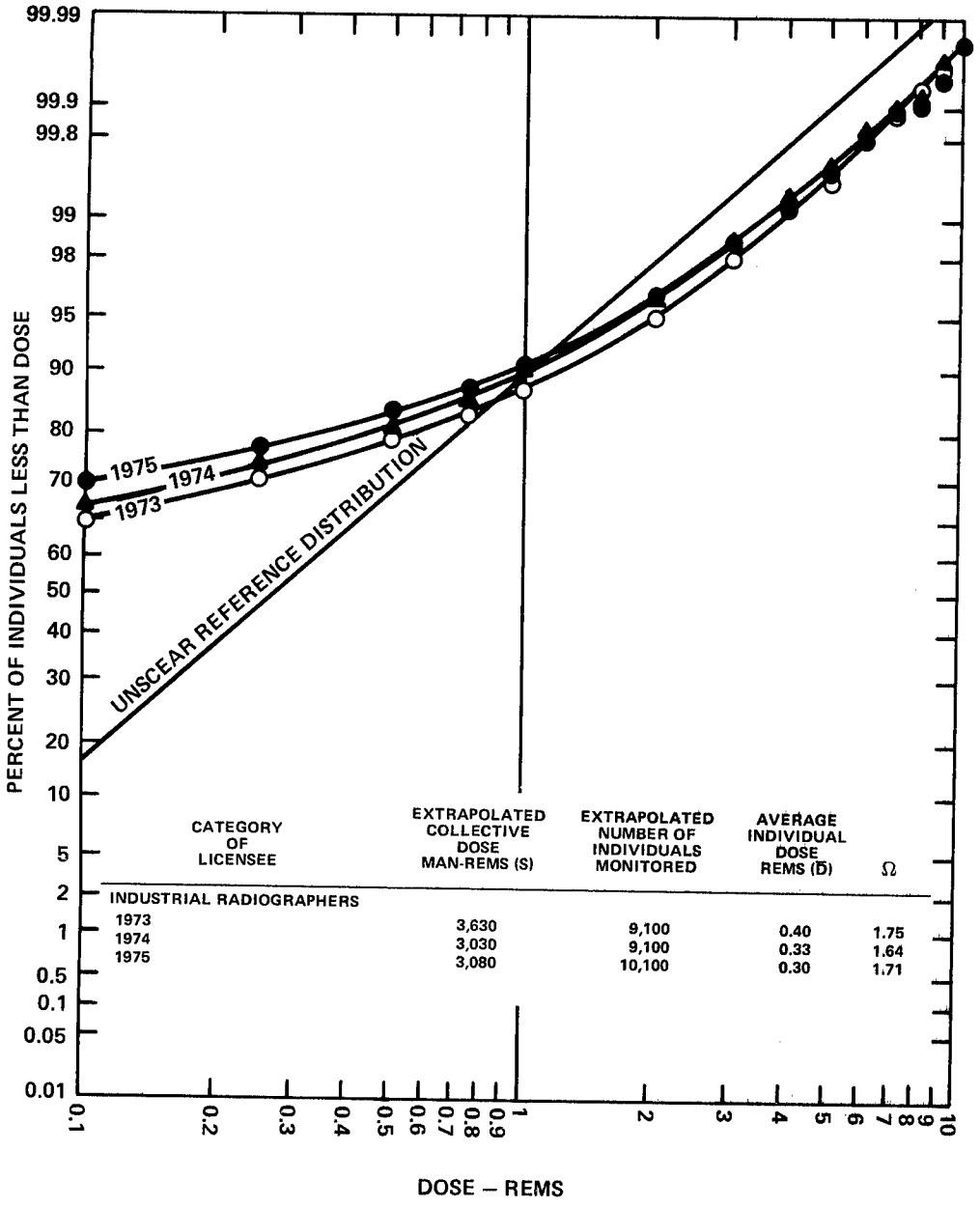
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS ($\bar{D}$)	Ω
1975 VOLUNTARY	22,900	245,500	0.10	0.88
1975 §20.407 REPORTS	28,960	80,570	0.36	2.00

Figure 6. Composite 1975 Voluntary Data and §20.407 Data



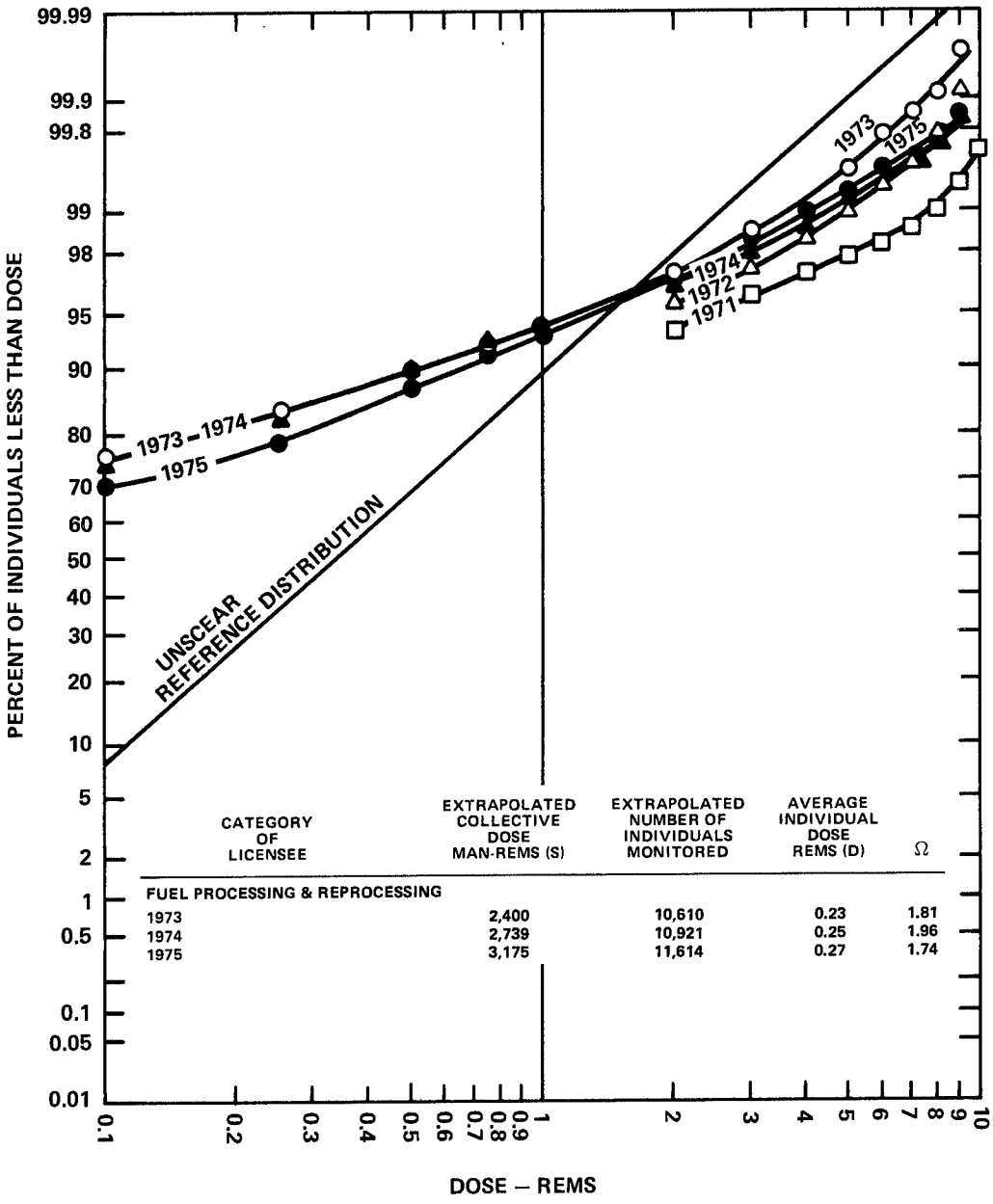
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS (D)	Ω
POWER REACTORS				
1973	14,337	44,795	0.32	2.29
1974	14,083	62,044	0.23	2.00
1975	21,270	54,763	0.39	2.07

Figure 7. §20.407 Power Reactor Data - 1973-1975



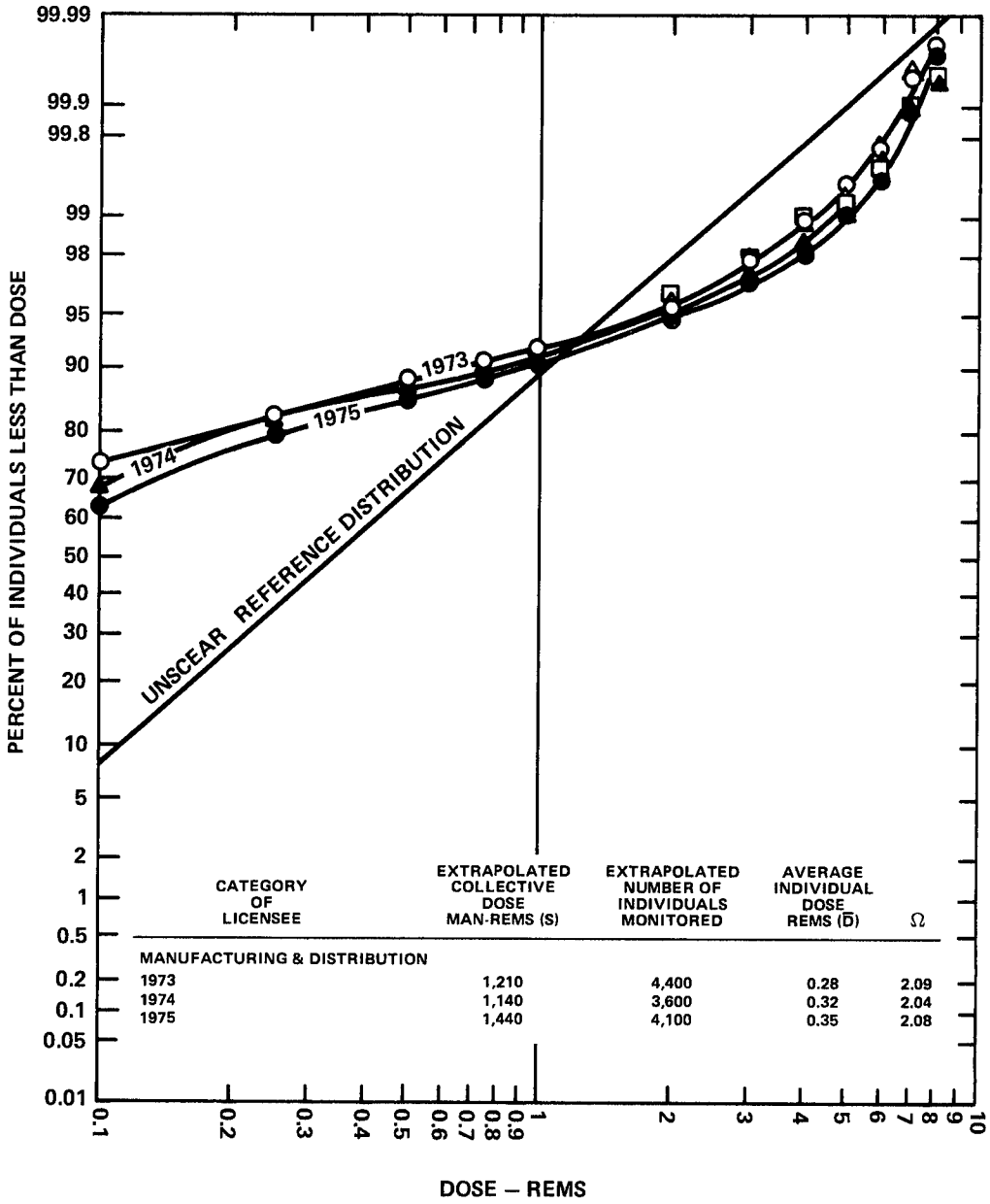
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS ($\bar{D}$)	Ω
INDUSTRIAL RADIOGRAPHERS				
1973	3,630	9,100	0.40	1.75
1974	3,030	9,100	0.33	1.64
1975	3,080	10,100	0.30	1.71

Figure 8. §20.407 Radiographer Data - 1973-1975



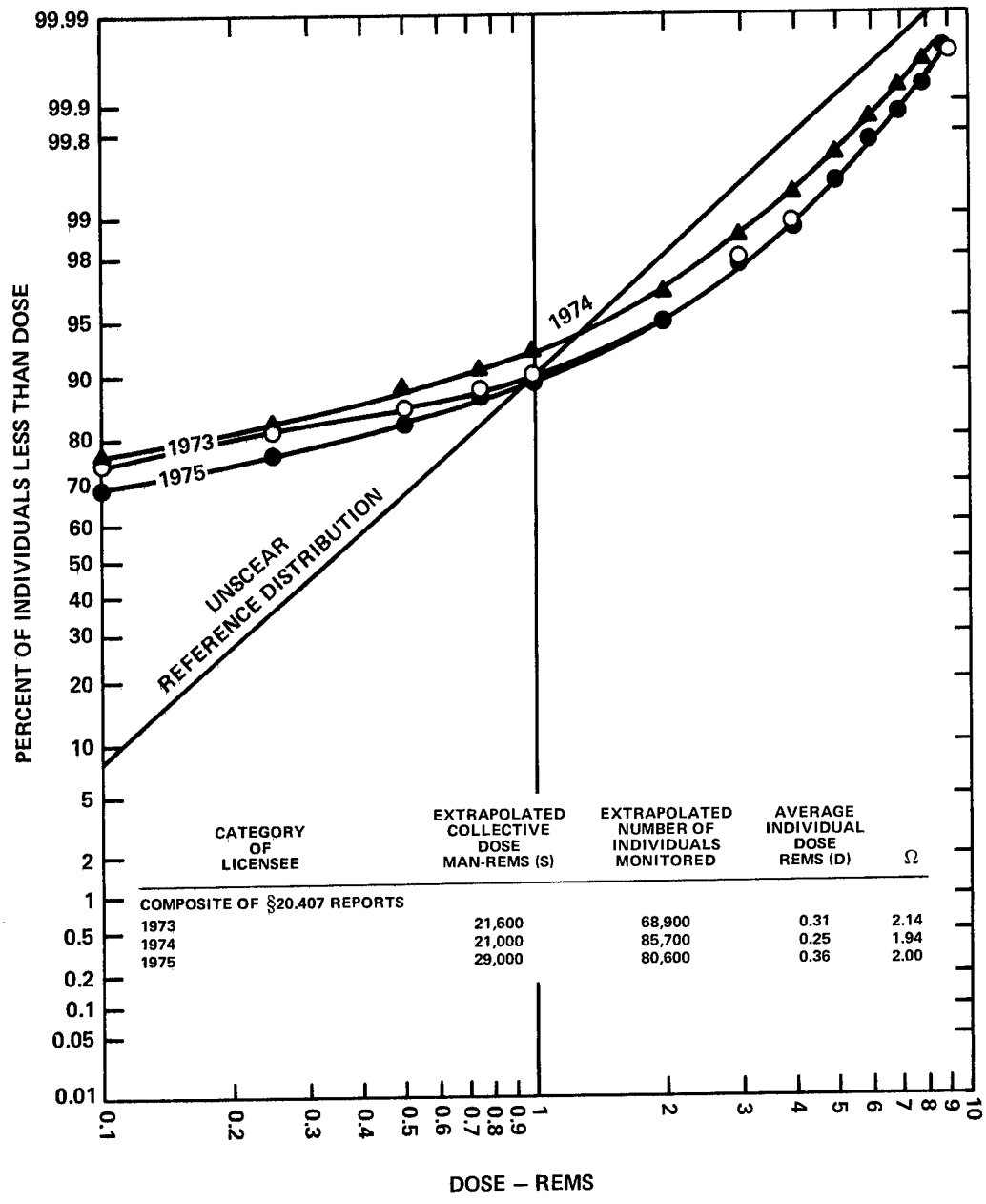
CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS (D)	Ω
FUEL PROCESSING & REPROCESSING				
1973	2,400	10,610	0.23	1.81
1974	2,739	10,921	0.25	1.96
1975	3,175	11,614	0.27	1.74

Figure 9. §20.407 Fuel Processing and Reprocessing Data - 1973-1975



CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS ($\bar{D}$)	Ω
MANUFACTURING & DISTRIBUTION				
1973	1,210	4,400	0.28	2.09
1974	1,140	3,600	0.32	2.04
1975	1,440	4,100	0.35	2.08

Figure 10. §20.407 Byproduct Manufacture and Distribution Data - 1973-1975



CATEGORY OF LICENSEE	EXTRAPOLATED COLLECTIVE DOSE MAN-REMS (S)	EXTRAPOLATED NUMBER OF INDIVIDUALS MONITORED	AVERAGE INDIVIDUAL DOSE REMS (D)	Ω
COMPOSITE OF §20.407 REPORTS				
1973	21,600	68,900	0.31	2.14
1974	21,000	85,700	0.25	1.94
1975	29,000	80,600	0.36	2.00

Figure 11. Composite Annual Summaries - 1973-1975 §20.407 Data

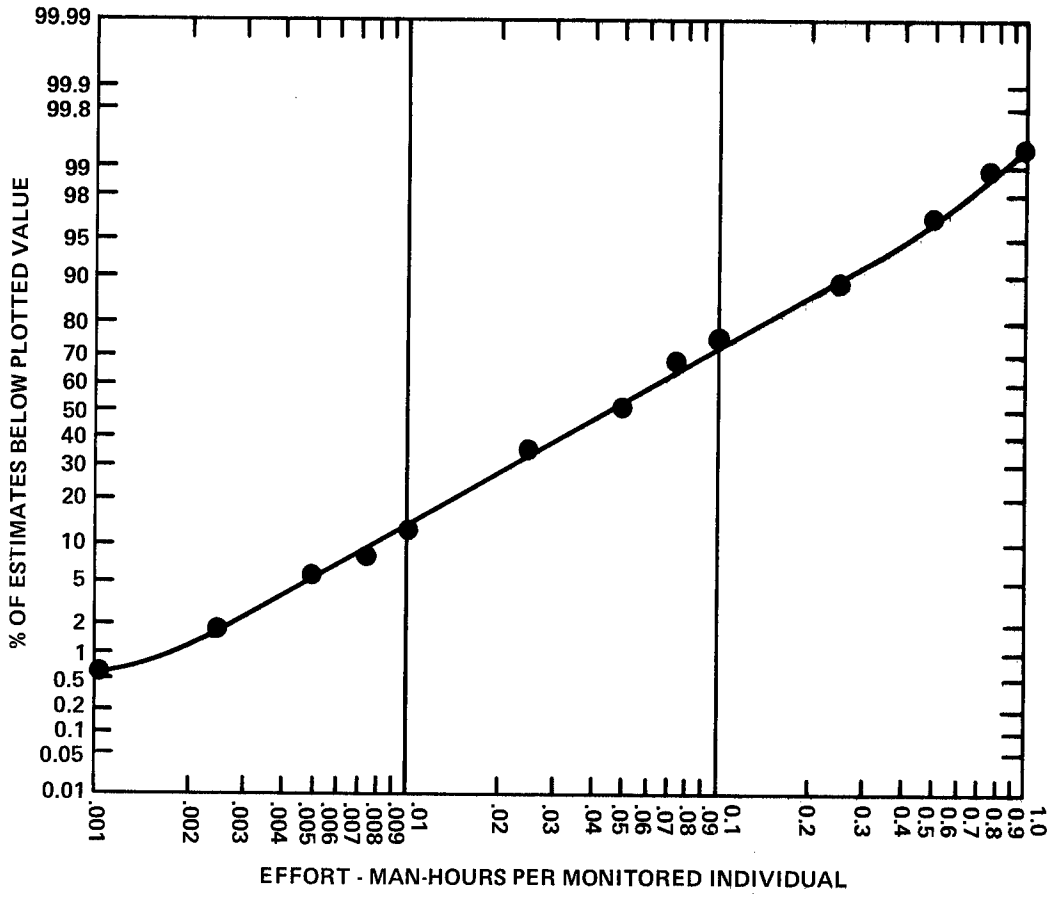


Figure 12. Effort Needed to Prepare Statistical Summary Report

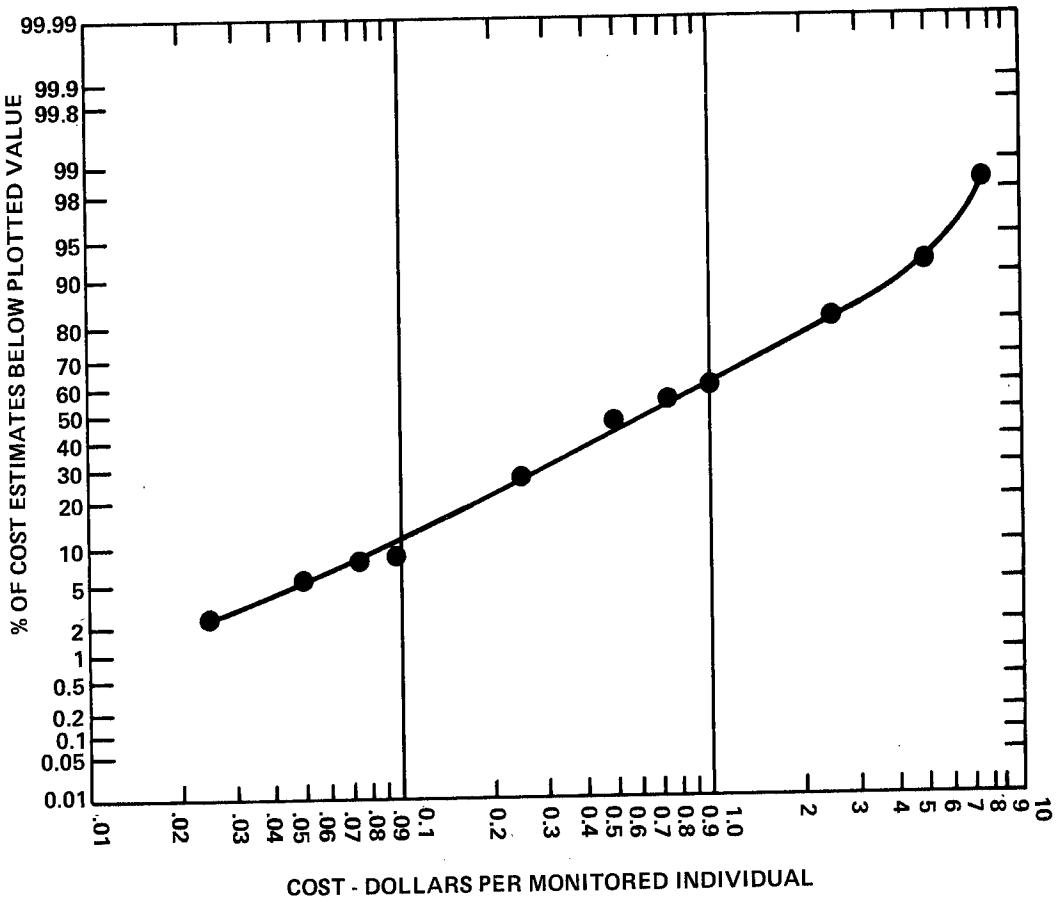


Figure 13. Cost of Preparing Annual Statistical Summary Report

*U.S. GOVERNMENT PRINTING OFFICE:1978 720-387/34 1-3